Remarks

Claim Status

Claims 1-8, 10-13 and 15-40 are currently pending in the application. Claims 1-7, 15-27 and 29-40 stand rejected. Claims 8 and 28 are objected to. Applicants present the foregoing Listing of Claims for the Examiner's convenience without introducing any claim amendments. Accordingly, claims 1-8, 10-13 and 15-40 are pending and presented for consideration.

Applicants' Claimed Invention

The present invention, as claimed in amended claims 1 and 15, relates to an apparatus and a corresponding method for monitoring electric motors. In particular, the apparatus comprises an antenna and a processor wherein the antenna provides a non-contact means for detecting radio frequency signals generated during the operation of the electric motor, while the processor determines one or more operational parameters of the electric motor from the detected radio frequency signals. As detailed in the specification as filed on page 5, paragraph 3 through page 8, paragraph 3, a number of factors influence "the ability of the arc to form, the duration of the arc and the arc intensity", see page 8, lines 6 and 7.

Processing of the "radio frequency signals generated by the arcing events in the electric motor" by the processor provides a means for determining one or more operational parameters of the electric motor. Put another way, the profile of the radio frequency signals generated by the arcing events in the electric motor allows for the measurement of a range of DC and AC electric motor diagnostics e.g. motor speed, acceleration or torque, and facilitates the location and identification of both electrical and mechanical faults within the electric motor.

The apparatus and method of amended claims 1 and 15, respectively, thus provide a portable, adjustable and non-intrusive means of measuring operational parameters of the electric motor.

Definitions

To assist the Examiner in distinguishing the present invention from those described in the prior art, the following definitions are referred to in the foregoing response and attached as Exhibits A, B and C hereto:

Radio Frequency: "A frequency at which coherent electromagnetic radiation energy is useful for communication purposes; roughly the range of 10 kilohertz to 110 gigahertz." McGraw-Hill Dictionary of Scientific and Technical Terms, McGraw-Hill, sixth edition, 2003, page 1736 (attached as Exhibit A).

Magnetic Flux: "The integral over a specified surface of the component of magnetic induction perpendicular to the surface." McGraw-Hill Dictionary of Scientific and Technical Terms, McGraw-Hill, sixth edition, 2003, page 1263 (attached as Exhibit B).

An extract from Wikipedia regarding "Electromagnetism" is also provided to assist further understanding. Wikipedia, available at http://en.wikipedia.org/wiki/Flux, last visited April 16, 2007 (attached as Exhibit C).

Applicants submit that radio frequency signals and magnetic flux are different. Magnetic flux is generated from moving current in wires. This flux is an inductive field, i.e., signals are coupled into other wires inductively, e.g., current transformers (CTs) or inductive coupler strips. In an inductive field environment, the field usually consists only of a magnetic field arising from the flow of current in wires. In inductive fields, any magnetic and electric fields are usually 90° out of phase.

Radio frequency signals are quite different. Radio frequency signals are signals radiated from a source, e.g., antennae or, as in the present invention, arcing events occurring in brush commutation within motors. These arcing events produce radiated electromagnetic fields (i.e., fields comprising magnetic and electric fields precisely in phase). Radiated fields are often referred to as non-inductive fields. The radiated field signals are picked up by antenna of the present invention. On the contrary, inductive fields, e.g., magnetic flux, cannot produce radiated fields and cannot be picked up by antennae.

Rejections Under 35 USC § 102: Canada

Claims 1-4, 7, 15, 16, 18-20, 22, 23, 27, 29, 30, 32-37, 39 and 40 are rejected under 35 U.S.C. § 102(b) as being anticipated by U.S. Patent No. 6,138,078 to Canada *et al.* ("Canada").

Canada relates to the field of machine monitors and, in particular, to an electric motor monitor capable of sensing and analyzing various stresses experienced by the motor during the life of the motor.

Canada's monitors (100 and 101) comprise a plurality of sensors (460a-d) that are located in and around the perimeter of both an electric motor (102) and an article of driven equipment (450). Canada's sensors (460a-d) may include sensors for sensing vibration, temperature and magnetic flux and are preferably tethered to the monitor (100) by cables. Alternatively, Canada's external sensors (460a-d) can be tethered by wireless means such as a radio frequency (RF) data link. See Canada, col. 13, line 30 to col. 14, line 60 and Figure 9.

Canada states at column 7, lines 9 and 10 that "*flux board 124 measures motor leakage flux much like an antenna*". This statement is at best an indication that an antenna may be employed to measure magnetic flux in Canada's system, without any further detail to the skilled reader how this could be achieved. It is not, however, a teaching of employing an antenna to detect radio-frequency signals generated by arcing events in the electric motor since, as discussed above, magnetic flux and radio frequency signals are two quite distinct physical parameters.

In contrast, Canada teaches employing wireless IR data links, RF links, or computer network communication modules to allow Canada's monitor (100 and 101) to communicate with a peripheral device e.g. the hub (554) and plant network (556) of Canada's Figure 10.

The Office action states in paragraph 3 that Canada teaches of all of the features of independent claims 1 and 15. In particular, the Office action states that "*the antenna detecting a radio frequency signal generated by arcing events in the electric motor and the processor processing the radio frequency signals generated by the arcing events in the electric motor to determine one or more operational parameters of the electric motor*" is disclosed within the teachings of Canada at Figure 9; column 2, lines 41 to 59; column 7, lines 7 to 15; and column 13, lines 30 to 44.

However, Applicants submit that Canada is silent with respect to arcing events within the electric motor (102) or the driven equipment (450) and, therefore, Canada is silent with respect to the detection of radio-frequency signals generated by such arcing events. What Canada does detect is **vibration, temperature** and **magnetic flux** parameters of the electric motor. See Canada at column 3, line 37 and column 13, lines 38 to 44. As discussed above, Canada's only reference to RF signals relates to the communication between Canada's monitor (101) and its corresponding sensors (460a-d) or Canada's monitor (100 and 101) and a peripheral device.

Applicants submit that if Canada's antenna (465b) were to detect radio frequencies generated by arcing events in the electric motor, this detection would result in significant interference that would prevent Canada's antenna from carrying out its desired function, i.e. to communicate with Canada's sensor (465a) or a peripheral device. Therefore, Canada actively teach the skilled reader away from employing an antenna to measure radio-frequency signals generated by such arcing events, as required by Applicants' independent claims 1 and 15.

With respect to claim 2, the Office action states that Canada teaches the feature of an antenna at column 11, lines 25 to 30. Applicants submit that the referenced paragraph of Canada relates to the conditioning of sensor signals, for example, by amplifying or frequency filtering. As detailed above, Canada does not disclose the use of an antenna to detect radio frequency signals generated by arcing events as one of Canada's sensors. Accordingly, Canada cannot teach or suggest screening background noise from a signal, which signal is not even detected by the system.

With respect to claims 3 and 4, the Office action states that Canada teaches the feature of a frequency matching unit for the antenna at column 6, line 60 to column 7, line 3. Applicants submit that the referenced paragraph of Canada relates to the use of electronic circuitry to condition outputs from Canada's sensors e.g. filtering flux and vibration signals. Canada does not disclose the use of Canada's antenna to detect radio frequency signals generated by arcing events as one of Canada's sensors. Accordingly, Canada cannot teach or suggest further employing a frequency matching unit to optimize the operation of such an antenna.

With respect to claim 7, the Office action states that Canada's sensor (124), shown in Canada's Figure 5, is a magnetic flux sensor. As detailed above, Applicants submit that Canada's flux sensor is not equivalent to Applicants' claimed antenna to detect radio frequency signals generated by arcing events even is in the form of a magnetic field probe.

With respect to claims 16, 23, 32, 33, 39 and 40, Applicants submit that Canada does not disclose detecting radio frequency signals generated by arcing events of an electric motor and, accordingly, Canada's Figure 9 cannot be considered to disclose associating these radio frequency signals to individual components of the electric motor. What Canada does measure is **vibration, temperature** and **magnetic flux**. Canada teaches that these parameters are employed as a diagnostic of the operation of Canada's overall electric motor. However, Canada does not

teach or suggest that these signals can be employed to give information about individual components within the electric motor.

With respect to claims 19 and 34, Applicants submit that Canada does not disclose the use of Canada's antenna to detect radio frequency signals generated by arcing events as one of Canada's sensors. Accordingly, Canada cannot teach or suggest carrying out FFT of such signals.

With respect to claims 20 and 22, Applicants submit that Canada does not disclose the use of Canada's antenna to detect radio frequency signals generated by arcing events as one of Canada's sensors. Accordingly, Canada cannot teach or suggest carrying out digital signal processing of such signals.

With respect to claim 27, as detailed above, Applicants do not believe that Canada teaches the method of independent claim 15. Accordingly, Canada cannot teach or suggest the self-calibration of such a method.

With respect to claim 35, as detailed above, Applicants do not believe that Canada teaches the method of claims 15 or 20. Accordingly, Canada cannot teach or suggest determining variations in the operational parameters of the electric motor.

Applicants submit that claims 1-4, 7, 15, 16, 18-20, 22, 23, 27, 29, 30, 32-37, 39 and 40 are patentable over Canada and respectfully request reconsideration and withdrawal of the rejection.

<u>Rejections Under 35 USC § 103: Canada in view of Lindsay</u>

Claims 5 and 6 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Canada in view of DE 003140319A1 to Lindsay *et al.* ("Lindsay"). Canada was discussed above. Lindsay does not cure the deficiencies of Canada. Specifically, Lindsay does not teach or suggest the use of an antenna to measure <u>radio frequency signals</u> and, in particular, radio frequency signals generated by arcing events in an electric motor.

Instead, Lindsay teaches an antenna employed to measure <u>magnetic flux</u>. In particular, Lindsay teaches electrically screening the antenna so as to avoid the problematic feature of switching capacitances, in conjunction with the inductance of the antenna winding, leading to resonances at specific frequencies.

Accordingly, Applicants submit that claims 5 and 6 are patentable over Canada in view of Lindsay and respectfully request reconsideration and withdrawal of the rejection.

Rejections Under 35 USC § 103: Blades and Canada in further view of Lu

Claim 17 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Canada in view of U.S. Patent No. 5,737,026 to Lu *et al.* ("Lu"). Canada was discussed above. Lu does not cure the deficiencies of Canada. Specifically, Lu does not teach or suggest the use of an antenna to measure radio frequency signals generated by arcing events in an electric motor

Lu teaches a video and data co-channel communication system. As highlighted by the Office action, Lu teaches employing an antenna as a non-intrusive sensor (120) to detect RF video signals at the rear of a television. The antenna is therefore employed in a similar manner to the communication antenna (465b) described by Canada.

Moreover, the person skilled in the art would have no motivation to combine the teachings of Canada and Lu, particularly in light of the negative teachings in Canada with respect to the use of antennas as RF sensors. Even if so motivated, the person skilled in the art would not be lead to the claimed invention.

Accordingly, Applicants submit that claim 17 is patentable over Canada in view of Lu and respectfully request reconsideration and withdrawal of the rejection.

Rejections Under 35 USC § 103: Blades and Canada in further view of Eryurek

Claim 21 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Canada in view of U.S. Patent No. 6,701,274 to Eryurek *et al.* ("Eryurek"). Canada was discussed above. Eryurek does not cure the deficiencies of Canada. Specifically, Eryurek does not teach or suggest the use of an antenna to measure radio frequency signals generated by arcing events in an electric motor.

Eryurek teaches pressure transmitters employed to sense process pressures and thereafter to display or transmit an output with a magnitude that is representative of the process pressure. The Office action indicated it to be of relevance to the present invention since it describes a method of Wavelet Analysis of digital signals.

Accordingly, Applicants submit that claim 21 is patentable over Canada in view of Eryurek and respectfully request reconsideration and withdrawal of the rejection.

Rejections Under 35 USC § 103: Canada in view of Blades

Claims 24-26, 31 and 38 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Canada in view of U.S. Patent No. 5,434,509 to Blades ("Blades"). Canada was discussed above. Blades does not cure the deficiencies of Canada. Specifically, Blades does not teach or suggest the use of an antenna to measure radio frequency signals generated by arcing events in an electric motor.

Blades relates to the field of detectors of electrical arcs on power lines to provide advanced warning of potentially dangerous conditions. See Blades, col. 1, lines 19 to 21. Important to the correct operation of Blades' invention is the fact that electrical arcing produced by an alternating voltage will extinguish each time the voltage across the arc drops below a value sufficient to sustain the arc, and will re-ignite each time the voltage across the arc exceeds the arc's ignition voltage. Therefore, arcs sustained by an alternating power source will necessarily extinguish at least twice every full cycle of the power source frequency. See Blades, col. 4, lines 36 to 43 and Figures 2, 3 and 5.

Of particular relevance to Applicants' invention is the section of Blades dedicated to the problem of avoiding false indications of dangerous arcing conditions due to noise from other sources, e.g. short-lived impulse noise from lamp dimmers, switching power supplies and the like; interference from local AM radio broadcast stations; arcing in electric motors with brush contacts; and communication signals from carrier-current transmitters. See Blades, col. 18, line 26 to col. 19 line 5. Each of these noise sources is described by Blades as being problematic and Blades describes various techniques to remove the presence of these noise sources from the high-frequency signal extracted from the power line.

Importantly, Blades states that the noise produced by an electric motor does not ever go to zero; it is present throughout the cycle. See Blades, col. 18, lines 55 to 57. Thus, "the lack of a gap in each half-cycle of the line frequency prevents false triggering of the arc detection device," as described in each of Blades' described operating methods. See Blades, col. 18, lines 59 to 62.

Applicants respectfully submit that Blades does not teach or suggest "an electric motor monitoring system" or "a method for monitoring an electric motor" as claimed in claims 1 and 15. Instead, Blades' described apparatus and methods are employed solely for use with power lines.

Furthermore, the person skilled in the art is actively led away from employing the method and apparatus taught by Blades to an electric motor. In fact, Blades teaches that its apparatus and methods are not capable of being employed with electric motors since the radio frequency signals generated by such motors do not produce the required "gaps" for monitoring the arcing events. It is this very fact which allows noise from such sources to be rejected.

For the foregoing reasons, Applicants submit that Blades and Canada are mutually exclusive. Further, even if the person skilled in the art were motivated to combine the teachings of Canada and Blades, such a combination does not produce the presently claimed invention. The described arc detector of Blades is not capable of detecting the radio-frequency signals associated with arcing events within electric motors since these signals do not produce the required "gaps" for monitoring the arcing events.

Accordingly, Applicants submit that claims 24-26, 31 and 38 are patentable over Canada in view of Blades and respectfully request reconsideration and withdrawal of the rejections.

Conclusion

Applicants respectfully submit that the foregoing arguments overcome the Examiner's rejections and that the pending claims are in condition for allowance. The Examiner is invited to contact Applicants' undersigned representative by telephone at the number listed below to discuss any outstanding issues.

Respectfully submitted,

Karen A. Sinclair

Date: December 19, 2007
Reg. No. 58,343

Karen A. Sinclair
Attorney for Applicant(s)
Kirkpatrick & Lockhart Preston
Gates Ellis LLP
State Street Financial Center
One Lincoln Street
Boston, Massachusetts 02111-2950

Tel. No.: (617) 261-3216
Fax No.: (617) 261-3175

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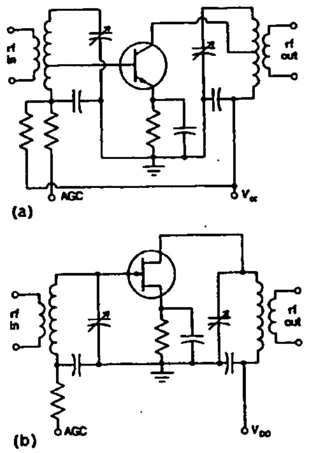
RADIO-FREQUENCY AMPLIFIER



Typical radio-frequency amplifier circuits with *(a)* bipolar transistor and *(b)* field-effect transistor. AGC = automatic gain control; V_{CC} = collector supply voltage; V_{DD} = drain supply voltage.

radio direction finding [NAV] A procedure for determining the bearing at a receiving point of the source of a radio signal by observing the direction of arrival of the wave front. { 'rād·ē·ō di'rek·shən ,fīnd·iŋ }

radio Doppler [ENG] Direct determination of the radial component of the relative velocity of an object by an observed frequency change due to such velocity. { 'rād·ē·ō 'däp·lər }

radio duct [GEOPHYS] An atmospheric layer, typically shallow and almost horizontal, in which radio waves propagate in an anomalous fashion; ducts occur when, due to sharp inversions of temperature or humidity, the vertical gradient of the radio index of refraction exceeds a critical value. { 'rād·ē·ō ,dəkt }

radio echo *See* radar return. { 'rād·ē·ō ,ek·ō }

radio echo observation [ENG] A method of determining the distance of objects in the atmosphere or outer space, in which a radar pulse is directed at the object and the time that elapses from transmission of the pulse to reception of a reflected pulse is measured. { 'rād·ē·ō ¦ekō ,äb·zər'vā·shən }

radioecology [ECOL] The interdisciplinary study of organisms, radionuclides, ionizing radiation, and the environment. { ¦rād·ē·ō·ē'käl·ə·jē }

radioelectric meteorology *See* radio meteorology. { ¦rād·ē·ō·i'lek·trik ,mēd·ē·ə'räl·ə·jē }

radio element [NUC PHYS] A radioactive isotope of an element, or a sample consisting of one or more radioactive isotopes of an element. { 'rād·ē·ō 'el·ə·mənt }

radio emission [ELECTROMAG] The emission of radio-frequency electromagnetic radiation by oscillating charges or currents. { 'rād·ē·ō i,mish·ən }

radio energy [ELECTROMAG] The energy carried by radio-frequency electromagnetic radiation. { 'rād·ē·ō ,en·ər·jē }

radio engineering [ENG] The field of engineering that deals with the generation, transmission, and reception of radio waves and with the design, manufacture, and testing of associated equipment. { 'rād·ē·ō ,en·jə'nir·iŋ }

radio facility chart *See* enroute chart. { 'rād·ē·ō fə'sil·əd·ē ,chärt }

radio facsimile system [COMMUN] A facsimile system in which signals are transmitted by radio rather than by wire. { 'rād·ē·ō fak'sim·ə·lē ,sis·təm }

radio fadeout [COMMUN] Increased absorption of radio waves passing through the lower layers of the ionosphere due to a sudden and abnormal increase in ionization in these regions; signals at receivers then fade out or disappear. Also known as fadeout. { 'rād·ē·ō 'fād,aùt }

radio fan-marker beacon *See* fan-marker beacon. { 'rād·ē·ō 'fan ,mär·kər ,bē·kən }

radio field intensity [ELECTROMAG] Electric or magnetic field intensity at a given location associated with the passage of radio waves. { 'rād·ē·ō 'fēld in,ten·səd·ē }

radio field-to-noise ratio [ELECTROMAG] Ratio, at a given location, of the radio field intensity of the desired wave to the noise field intensity. { 'rād·ē·ō 'fēld tə 'nòiz ,rā·shō }

radio fix [COMMUN] Determination of the position of the source of radio signals by obtaining cross bearings on the transmitter with two or more radio direction finders in different locations, then computing the position by triangulation. [NAV] **1.** Determination of the position of a vessel or aircraft equipped with direction-finding equipment by ascertaining the direction of radio signals received from two or more transmitting stations of known location and then computing the position by triangulation. **2.** Determination of position of an aircraft in flight by identification of a radio beacon or by locating the intersection of two radio beams. { 'rād·ē·ō ,fiks }

radio fixing aid [NAV] Equipment making use of radio to assist in the determination of a geographical position. { 'rād·ē·ō 'fiks·iŋ ,ād }

radio frequency [ELECTROMAG] A frequency at which coherent electromagnetic radiation of energy is useful for communication purposes; roughly the range from 10 kilohertz to 100 gigahertz. Abbreviated rf. { 'rād·ē·ō ,frē·kwən·sē }

radio-frequency alternator [ELEC] A rotating-type alternator designed to produce high power at frequencies above power-line values but generally lower than 100,000 hertz; used chiefly for high-frequency heating. { 'rād·ē·ō ¦frē·kwən·sē 'ól·tə,nād·ər }

radio-frequency amplifier [ELECTR] An am... amplifies the high-frequency signals commonly ... communications. { 'rād·ē·ō ¦frē·kwən·sē 'am·plə... }

radio-frequency bandwidth [COMMUN] Band o... cies comprising 99% of the total radiated power of ... transmission extended to include any discrete fre... which the power is at least 0.25% of the total radi... { 'rād·ē·ō ¦frē·kwən·sē 'band,width }

radio-frequency cable [ELECTROMAG] A ca... electric conductors separated from each other by a... homogeneous dielectric or by touching or interlock... beads; designed primarily to conduct radio-freque... with low losses. Also known as RG line. { '... kwən·sē ,kā·bəl }

radio-frequency cavity preselector [ELECTROMAG] ... able cavity resonator in an ultra-high-frequency cir... is similar in function to a tuned resonant circuit. ... ¦frē·kwən·sē 'kav·əd·ē ,prē·si'lek·tər }

radio-frequency choke [ELEC] A coil designed ... specifically to block the flow of radio-frequency cu... passing lower frequencies or direct current. { '... kwən·sē ,chōk }

radio-frequency component [COMMUN] Portion ... nal or wave which consists only of the radio-frequen... tions, and not including its audio rate of change in ... frequency. { 'rād·ē·ō ¦frē·kwən·sē kəm,pō·nənt }

radio-frequency current [ELEC] Alternating curr... a frequency higher than 10,000 hertz. { 'rād·ē·ō ... sē ,kə·rənt }

radio-frequency filter [ELECTR] An electric filt... enhances signals at certain radio frequencies or atten... nals at undesired radio frequencies. { 'rād·ē·ō ¦fre... ,fil·tər }

radio-frequency generator [ELECTR] A generat... of supplying sufficient radio-frequency energy at th... frequency for induction or dielectric heating. { '... kwən·sē 'jen·ə,rād·ər }

radio-frequency head [ENG] Unit consisting ... transmitter and part of a radar receiver, the two co... package for ready removal and installation. { '... kwən·sē 'hed }

radio-frequency heating *See* electronic heating. ... ¦frē·kwən·sē 'hēd·iŋ }

radio-frequency interference [COMMUN] ... from sources of energy outside a system or system... trasted to electromagnetic interference generated ... tems. Abbreviated RFI. { 'rād·ē·ō ¦frē·kwən·sē ... əns }

radio-frequency line *See* radio-frequency transmi... { 'rād·ē·ō ¦frē·kwən·sē ,līn }

radio-frequency measurement [ELECTR] The ... measurement of frequencies above the audible ran... of various techniques, such as a calibrated oscillator ... means of comparison with the unknown frequen... counting or scaling device which measures the ... of events occurring during a given time interval, or ... circuit for producing a direct current proportiona... quency of its input signal. { 'rād·ē·ō ¦frē·kw... ər·mənt }

radio-frequency oscillator [ELECTR] An ... generates alternating current at radio frequen... ¦frē·kwən·sē 'äs·ə,lād·ər }

radio-frequency power supply [ELECTR] ... power supply in which the output of a radio-frequ... is stepped up by an air-core transformer to the ... required for the second anode of a cathode-ray tu... fied to provide the required high direct-curren... in some television receivers. { 'rād·ē·ō ¦frē·k... sə,plī }

radio-frequency preheating [ENG] Preheating ... molding materials by radio frequencies of 10-10... per second to facilitate the molding operation or ... molding-cycle time. Abbreviated rf preheating. ... ¦frē·kwən·sē ¦prē'hēd·iŋ }

radio-frequency pulse [COMMUN] A radio-fre... rier that is amplitude-modulated by a pulse; the a... the modulated carrier is zero before and after the p... known as radio pulse. { 'rād·ē·ō ¦frē·kwən·sē ...

geographic latitude. Also known as magnetic daily variation. { mag'ned·ik dī'ərn·əl ,ver·ē'ā·shən }

...tic document sorter-reader *See* magnetic character ... { mag'ned·ik ¦däk·yə·mənt 'sȯrd·ər 'rēd·ər }

...tic domain *See* ferromagnetic domain. { mag'ned·ik ... }

...tic domain memory *See* domain-tip memory. ...ned·ik də'mān ,mem·rē }

...ic double refraction [OPTICS] The double refrac... light passing through certain substances when the sub... is placed in a transverse magnetic field. { mag'ned·ik ...frak·shən }

...ic drag dynamometer *See* eddy-current brake. ...ik ¦drag ,dī·nə'mäm·əd·ər }

...ic drum *See* drum. { mag'ned·ik 'drəm }

...ic drum receiving equipment [ELECTR] Radar ... for detection of targets beyond line of sight using ... reflection and very low power. { mag'ned·ik ...v·iŋ i,kwip·mənt }

...ic drum storage *See* drum. { mag'ned·ik ¦drəm ... }

...ic earphone [ENG ACOUS] An earphone in which ...s in electric current produce variations in a magnetic ...using motion of a diaphragm. { mag'ned·ik 'ir,fōn }

...ic element [ENG] That part of an instrument produc... influenced by magnetism. [GEOPHYS] Magnetic dec..., dip, or intensity at any location on the surface of the ... { mag'ned·ik 'el·ə·mənt }

...ic energy [ELECTROMAG] The energy required to ... magnetic field. { mag'ned·ik 'en·ər·jē }

...ic equator [GEOPHYS] That line on the surface of ... connecting all points at which the magnetic dip is ... Also known as aclinic line. { mag'ned·ik i'kwād·ər }

...ic ferroelectric [SOLID STATE] A substance which ...s both magnetic ordering and spontaneous electric ...tion. { mag'ned·ik ¦fer·ō·i'lek·trik }

...ic field [ELECTROMAG] **1.** One of the elementary ... nature; it is found in the vicinity of a magnetic body ...-carrying medium and, along with electric field, in a ... charges moving through a magnetic field experience ...entz force. **2.** *See* magnetic field strength. ...ed·ik 'fēld }

...ic field intensity *See* magnetic field strength. ...ed·ik 'fēld in,ten·səd·ē }

...ic field sensor [ENG] A proximity sensor that uses ...ation of a reed switch and a magnet to detect the ... of a magnetic field. { mag'ned·ik fēld ,sen·sər }

...ic field strength [ELECTROMAG] An auxiliary vec... used in describing magnetic phenomena, whose curl, ...se of static charges and currents, equals (in meter-...second units) the free current density vector, indepen... the magnetic permeability of the material. Also known ...ic field; magnetic field intensity; magnetic force; ... intensity; magnetizing force. { mag'ned·ik 'fēld ... }

...ic film *See* magnetic thin film. { mag'ned·ik 'film }

...ic filter [CHEM ENG] Filtration device in which the ...a is magnetized to trap and remove fine iron from ... liquid suspensions being filtered. { mag'ned·ik ... }

...ic firing circuit [ELECTR] A type of firing circuit in ... capacitor is discharged through the igniter by saturat...r, which is connected in series with the capacitor; ... in ignitron rectifiers to obtain longer life and greater ... than is possible with thyratron firing tubes. ...ik 'fīr·iŋ ,sər·kət }

...ic flaw detector [ELECTROMAG] A flaw detector in ...ous object is magnetized with an electromagnet or ... magnet and sprayed with magnetic particles or a ...taining fine suspended magnetic particles which ...face or near-surface flaws. { mag'ned·ik 'flȯ ... }

...ic fluid [MATER] A mixture of iron particles in oil ...it; viscosity increases sharply in a strong magnetic ... { ...ned·ik 'flü·əd }

...ic fluid clutch [MECH ENG] A friction clutch that is ... magnetizing a liquid suspension of powdered iron ...en pole pieces mounted on the input and output shafts. Also known as magnetic clutch. { mag'ned·ik ¦flü·əd 'kləch }

magnetic flux [ELECTROMAG] **1.** The integral over a specified surface of the component of magnetic induction perpendicular to the surface. **2.** *See* magnetic lines of force. { mag 'ned·ik 'fləks }

magnetic flux density [ELECTROMAG] A vector quantity that is used as a quantitative measure of magnetic field; the force on a charged particle moving in the field is equal to the particle's charge times the cross product of the particle's velocity with the magnetic flux density (SI units). Also known as magnetic displacement; magnetic induction; magnetic vector. { mag'ned·ik 'fləks ,den·səd·ē }

magnetic flux quantum [ELEC] A fundamental unit of magnetic flux, the total magnetic flux in a fluxoid in a type II superconductor, equal to $h/(2e)$, where h is Planck's constant and e is the magnitude of the electron charge, or approximately 2.07×10^{-15} weber. { mag,ned·ik 'fləks ,kwän·təm }

magnetic focusing [ELECTROMAG] Focusing a beam of electrons or other charged particles by using the action of a magnetic field. { mag'ned·ik 'fō·kə·siŋ }

magnetic force *See* magnetic field strength. { mag'ned·ik 'fȯrs }

magnetic force microscopy [ENG] The use of an atomic force microscope to measure the gradient of a magnetic field acting on a tip made of a magnetic material, by monitoring the shift of the natural frequency of the cantilever due to the magnetic force as the tip is scanned over the sample. { mag¦ned·ik ¦fȯrs mī'krä·skə·pē }

magnetic force parameter [PL PHYS] A dimensionless number used in magnetofluid dynamics, equal to the product of the square of the magnetic permeability, the square of the magnetic field strength, the electrical conductivity, and a characteristic length, divided by the product of the mass density and the fluid velocity. Symbolized N. { mag'ned·ik ¦fȯrs pə'ram·əd·ər }

magnetic force welding [MET] A welding process in which the mechanical force is exerted by a magnetic field. { mag'ned·ik ¦fȯrs 'weld·iŋ }

magnetic forming [MET] The forming of metal into desired shapes by using strong magnetic fields, produced by charging a large capacitor bank and then discharging it into an induction coil in less than 10^{-6} second, to push the metal against a forming die. { mag'ned·ik 'fȯr·miŋ }

magnetic friction clutch [MECH ENG] A friction clutch in which the pressure between the friction surfaces is produced by magnetic attraction. Also known as magnetic clutch. { mag'ned·ik 'frik·shən ,kləch }

magnetic gap [ELECTROMAG] The space between a magnet's pole faces. { mag'ned·ik 'gap }

magnetic grenade [ORD] Small explosive charge with attached magnets, designed to be thrown or placed against tanks; the magnets hold the explosive in place until detonated by a time fuse. Also known as magnetic charge. { mag'ned·ik grə'nād }

magnetic groups *See* Shubnikov groups. { mag'ned·ik 'grüps }

magnetic hardness comparator [ENG] A device for checking the hardness of steel parts by placing a unit of known proper hardness within an induction coil; the unit to be tested is then placed within a similar induction coil, and the behavior of the induction coils compared; if the standard and test units have the same magnetic properties, the hardness of the two units is considered to be the same. { mag'ned·ik 'härd·nəs kəm,par·əd·ər }

magnetic head [ELECTR] The electromagnet used for reading, recording, or erasing signals on a magnetic disk, drum, or tape. Also known as magnetic read/write head. { mag'ned·ik 'hed }

magnetic heading [NAV] Heading relative to magnetic north, with the compass heading corrected for deviation. { mag'ned·ik 'hed·iŋ }

magnetic hysteresis [ELECTROMAG] Lagging of changes in the magnetization of a substance behind changes in the magnetic field as the magnetic field is varied. Also known as hysteresis. { mag'ned·ik ,his·tə'rē·səs }

magnetic induction *See* magnetic flux density. { mag'ned·ik in'dək·shən }

Electromagnetism

Flux definition and theorems

An example of the second definition of flux is the magnitude of a river's current, that is, the amount of water that flows through a cross-section of the river each second. The amount of sunlight that lands on a patch of ground each second is also a kind of flux.

To better understand the concept of flux in Electromagnetism, imagine a butterfly net. The amount of air moving through the net at any given instant in time is the flux. If the wind speed is high, then the flux through the net is large. If the net is made bigger, then the flux would be larger even though the wind speed is the same. For the most air to move through the net, the opening of the net must be facing the direction the wind is blowing. If the net opening is parallel to the wind, then no wind will be moving through the net. (These examples are not very good because they rely on a transport process and as stated in the introduction, transport flux is defined differently than E+M flux.) Perhaps the best way to think of flux abstractly is "How much stuff goes through your thing", where the stuff is a field and the thing is the imaginary surface.

As a mathematical concept, flux is represented by the surface integral of a vector field,

$$\Phi_f = \int_S \mathbf{F} \cdot \mathbf{dA}$$

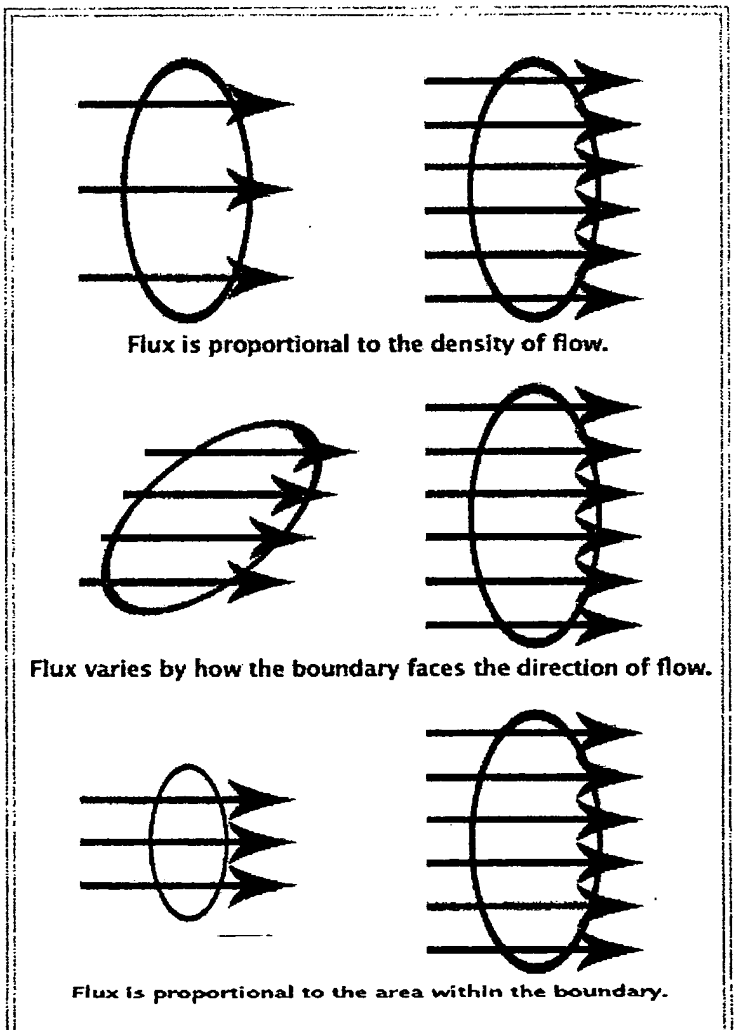
where

> **F** is a vector field,
> **dA** is the vector area of the surface S, directed as the surface normal,
> Φ_f is the resulting flux.

The surface has to be orientable, i.e. two sides can be distinguished: the surface does not fold back onto itself. Also, the surface has to be actually oriented, i.e. we use a convention as to flowing which way is counted positive; flowing backward is then counted negative.

The surface normal is directed accordingly, usually by the right-hand rule.

Conversely, one can consider the flux the more fundamental quantity and call the vector field the flux density.



The flux visualized. The rings show the surface boundaries. The red arrows stand for the flow of charges, fluid particles, subatomic

particles, photons, etc. The number of arrows that pass through each ring is the flux.

Often a vector field is drawn by curves (field lines) following the "flow"; the magnitude of the vector field is then the line density, and the flux through a surface is the number of lines. Lines originate from areas of positive divergence (sources) and end at areas of negative divergence (sinks).

See also the image at right: the number of red arrows passing through a unit area is the flux density, the curve encircling the red arrows denotes the boundary of the surface, and the orientation of the arrows with respect to the surface denotes the sign of the inner product of the vector field with the surface normals.

If the surface encloses a 3D region, usually the surface is oriented such that the **outflux** is counted positive; the opposite is the **influx**.

The divergence theorem states that the net outflux through a closed surface, in other words the net outflux from a 3D region, is found by adding the local net outflow from each point in the region (which is expressed by the divergence).

If the surface is not closed, it has an oriented curve as boundary. Stokes theorem states that the flux of the curl of a vector field is the line integral of the vector field over this boundary. This path integral is also called circulation, especially in fluid dynamics. Thus the curl is the circulation density.

We can apply the flux and these theorems to many disciplines in which we see currents, forces, etc., applied through areas.

Maxwell's equations

The flux of electric and magnetic field lines is frequently discussed in electrostatics. This is because in Maxwell's equations in integral form involve integrals like above for electric and magnetic fields.

For instance, Gauss's law states that the flux of the electric field out of a closed surface is proportional to the electric charge enclosed in the surface (regardless of how that charge is distributed). The constant of proportionality is the reciprocal of the permittivity of free space.

Its integral form is:

$$\oint_A \epsilon_0 \mathbf{E} \cdot d\mathbf{A} = Q_A$$

where

$\mathbf{E}$ is the electric field,
$d\mathbf{A}$ is the area of a differential square on the surface A with an outward facing surface normal defining its direction,
Q_A is the charge enclosed by the surface,
ϵ_0 is the permittivity of free space
$\oint_A$ is the integral over the surface A.

Either $\oint_A \epsilon_0 \mathbf{E} \cdot d\mathbf{A}$ or $\oint_A \mathbf{E} \cdot d\mathbf{A}$ is called the **electric flux**.

Faraday's law of induction in integral form is:

$$\oint_C \mathbf{E} \cdot d\mathbf{l} = -\int_{\partial C} \frac{d\mathbf{B}}{dt} \cdot d\mathbf{s} = -\frac{d\Phi_D}{dt}$$

The magnetic field density, also called magnetic flux density, is denoted by $\mathbf{B}$. Its flux is called the magnetic flux. The time-rate of change of the magnetic flux through a loop of wire is minus the electromotive force created in that wire. The direction is such that if current is allowed to pass through the wire, the electromotive force will cause a current which "opposes" the change in magnetic field by itself producing a magnetic field opposite to the change. This is the basis for inductors and many electric generators.

Poynting vector

The flux of the Poynting vector through a surface is the electromagnetic power, or energy per unit time, passing through that surface. This is commonly used in analysis of electromagnetic radiation, but has application to other electromagnetic systems as well.